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6. AUTHOR(S)
Rostislav Serota

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Physics
University of Cincinnati
Cincinnati, Ohio 45221-0011

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In the course of the reported project we studied transport and thermodynamic properties of ultra-small electronic microstructures, known as mesoscopic, using various theoretical approaches and techniques. The main goal of this research is the improved characterization of and understanding of limitations on quantum electronic devices. We obtained several important results and breakthroughs in our analysis of hopping conduction in Si-MOSFETs, far infra-red absorption in metal-insulator composites, and orbital magnetism of metals and quantum dots in semiconductor heterostructures.

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FINAL REPORT

DR. ROSTISLAV SEROTA

WEDNESDAY, AUGUST 12, 1992

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DEPARTMENT OF PHYSICS

UNIVERSITY OF CINCINNATI

CINCINNATI, OH 45221-0011

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Final Report

Prof. Rostislav Serota
Department of Physics
University of Cincinnati
Cincinnati, OH 45221-0011
Grant No. DAAL03-89-K-0108

In the course of the reported project we studied transport and thermodynamic properties of ultra-small electronic microstructures, known as mesoscopic, using various theoretical approaches and techniques. The main goal of this research is the improved characterization of and understanding of limitations on quantum electronic devices. Our most important findings can be summarized as follows:

1. Resistance distribution function was obtained for the variable-range hopping (Mott) conduction mechanism in quasi-one-dimensional Si-MOSFET devices. Effects of the finite width of the device have been investigated and the "bottleneck" phenomenon, whereby an electron in a restricted geometry cannot hop around an energy barrier, has been predicted.

2. Implication of current conservation for the conductance of strongly disordered metals has been explored and shown to have a dramatic impact on their non-self-averaging properties (conductance distribution function).

3. A new theoretical approach to absorption of electromagnetic radiation in small metal particle - insulator composites has been developed which enabled us to propose a plausible explanation of anomalous far infra-red absorption and the red-shift of surface plasmon.

4. The most comprehensive account of orbital magnetic response of mesoscopic systems has been accomplished, addressing such topics as the fluctuations of Landau and Aharonov-Bohm susceptibilities, fluctuations of the electron spin-polarization and diamagnetic currents (including the prediction of a dramatic inhomogeneous broadening of the Knight shift in NMR), interplay of spin and orbital degrees of freedom in metals with paramagnetic impurities, effects of electron-electron interactions and sample geometries, average response, etc. Most importantly, we put forward a novel concept that the magnetic response of mesoscopic systems should be addressed in atomic (nuclear) terms rather than using conventional approaches.

5. A long-standing problem of the incorporation of repulsive level statistics in the evaluation of the orbital response at near-zero temperature has been solved. A new angle, from the quantum chaos perspective, to mesoscopic systems is being developed and successfully applied.

6. Magnetism of quantum dot structures created at semiconductor interfaces has been studied in detail. We predicted the large orbital response and formulated a variant of the Hund's rule in the weak magnetic field regime and worked out the three electron problem in the strong magnetic field. The interactions effects have been shown crucial and the effect of the gate shape and its location with respect to the two-dimensional electron gas is currently under investigation.

Published and submitted articles

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11. "Orbital magnetism of quantum dots: a signature of electron-electron interactions," with Y.H. Zeng and B. Goodman, submitted to the Physical Review.
12. "Chaotic quantum billiards in magnetic fields: a semiclassical analysis of mesoscopic effects," submitted to Solid State Communications.

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